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Evaluation and Design of Auditory Feedback for a Mobile Outdoor Training Assistant

Ekaterina Kurdyukova, Jochen Hahnen, Wolfgang Prinz, Wido Wirsam

Fraunhofer FIT / RWTH Aachen University

Abstract

This paper presents a study about the design and evaluation of auditory feedback for a mobile outdoor training assistant. The requirement analysis and evaluation has been conducted with sportsmen from different disciplines. This led to a new auditory and interaction design of the mobile client. In this paper we report the findings of the auditory component and we provide recommendations for the use of signal or voice feedback for different training situations.

1 Introduction

Personal mobile assistants are beneficially employed in various areas of modern life. They help professionals to improve their work performance, guide travelers and navigate drivers, support learning process, and amuse us in our leisure time. In outdoor sports the mobile assistants serve as personal trainers, they collect training-related data, and accompany athletes like training mates. Location-awareness adds further opportunities to mobile sports systems such as spatial navigation and other track-related services, e.g. information about remarkable objects on the track. These additional services diversify the training routine and make it more emotional and entertaining. Motivation plays an important role in the training process. Mobile assistants support this goal as well: for instance, music, audio signals or speech feedback can guide and incite sportsmen. Competition spirit is another source of training motivation; it stimulates athletes to improve their achievements and set new records.

Although modern mobile technologies allow incorporation of various training-supporting functions into one application, most of the training assistants focus just on one functionality – navigation, data feedback, musical entertainment and disregard the other important functions. A literature study and the analysis of existing training assistants yielded four essential functions that a training assistant should support:

- Performance feedback: reflection of actual user achievements during the training and the overview of his results after the training.
- Navigation: guidance on unfamiliar tracks.
- Competition support: motivating factor to strengthen the physical abilities.
- Entertainment: music or other amusing features aimed at distracting from training fatigue.

In this paper we present the design, implementation and evaluation of a universal training assistant that integrates these essential functions with a special focus on the design of the auditory feedback for these functions. As implementation platform we have selected the Mobota system (Hahnen et al. 2007) since Mobota provides a mobile client to record tracks, and to navigate including a competition mode that enabled us to add audio feedback. The client is combined with a community platform to enable the exchange of track and performance data. After an overview of related work and systems, we present our requirement analysis, the system design and the evaluation results for the newly added auditory feedback.

2 Related Work

Nowadays, mobile applications for sports attract attention of the academic and the business world. Existing research projects as well as products are equipped with many different functions, providing diverse solutions of user interfaces. According to our studies the essential functions that a training assistant needs to support are performance feedback, navigation on the track, competition, and entertainment. In this section we provide an overview of existing training assistants and analyze how they support the essential functions. The analyzed systems focus on various training-supporting functions; they offer diverse solutions for user interfaces.

	MOP ET	MP-Train	IM4-Sports	Gar-min	Vida-One	FRW D	Nokia	Nike+ iPod	Run. GPS
Performance Feedback									
Navigation									
Competition									
Entertainment									

Table 1: Comparison of auditory UI features – colored cells indicate a support of this feature

In the framework of this paper we cannot provide a detailed description of all systems that have been investigated (Buttissi et al. 2006; Oliver & Flores-Mangas 2006; Wijnalda & Pauws 2005; Garmin 2007; VidaOne 2007; FRWD 2007; Nokia 2007; Nike 2007; RunGPS

2008). Therefore we condensed the review into Table 1 that illustrates how the four basic functions of outdoor training are supported by the systems. The table indicates that none of the examined systems provides all four essential functions. Most applications tend to exploit visual user interface, and undervalue the potential of auditory UI (Donker & Blenn 2007).

3 Requirement Analysis

In this section we describe our requirements elicitation. Since the target group of Mobota application consists of runners, cyclists, walkers, etc., the interviewed persons were chosen among professional as well as hobby sportsmen. In total 12 persons were interviewed, half of them can be called professionals: they perform triathlon in the second national league. The other interviewed sportsmen do sports occasionally with the purpose of personal recreation.

The interviewed persons were aged between 21 and 40 years old (9 male and 3 female). The professional backgrounds are: 5 students, 3 natural scientists, one policeman, and 3 professionals. The interviewees had different experiences with mobile devices: 50% do not use a PDA, 2 of them possess smart phones, but all have mobile phones. None of the interviewed persons had previous experience with Mobota. We concentrated mostly on running sport, with a secondary focus on cyclists. Interviews were conducted in an opened way, individually with each sportsman in form of a moderated discussion.

First goal of the interviews was to understand the rationales of the sportsmen in choosing a new track. The answers helped us build a vision what aspects are important to know and to see in advance when planning a new trip. The common way for navigation on unfamiliar tracks is to use a map. Interviewed sportsmen usually use paper maps, digital maps on PDA, bike roads maps, and even hand drawn maps. Often sportsmen of one neighborhood train on the same or similar tracks. For a person who joins such sports community it can be interesting to know impressions, tips, and useful notes about a track the “newbie” wants to take. Thus we asked sportsmen to recommend us their favorite track and provide some additional descriptions what they find important for us to know in advance. Moreover, we asked which kind of information about a new track is interesting for them. This information was important for the design of auditory hints for navigation on a new track.

We investigated which data is highly demanded by sportsmen during and after the training, as well as special training moments or events that are important to be aware of. We also asked if the sportsmen analyze their trainings, and if they trace their progress and how they do that. To discover how sportsmen behave in a competition atmosphere, we asked them to imagine a race situation. The rival runs closely and is about to overtake the sportsman. Which data is important to keep track of and to compare? Which moments of the race are important?

The requirements gathered from these interviews include the interaction guidelines for mobile assistants and guidelines for acoustical and graphical design. During the training the visual attention to the device is lacking. The users tend to bind the device around the arm or at the belt so that its position is fixed. Consequently, it is hard to look at the screen; the wide possibilities of visual design are restricted. Thus, a beneficial alternative to visual output is the feedback via the audio channel. Unobtrusive sounds can convey necessary information to the user and appear only in moments when the user needs them. They don't require any additional actions from the user side; they can be easily interpreted or just ignored. That is why we decided to exploit the audio user interface as the main mechanism to provide users with the feedback in critical training situations.

Which moments of outdoor training can be considered critical and, hence, need audio support? After thorough analysis of the user interviews, we define the following training moments as those situations that need to be supported by audio:

Time unit is over. Although the unit size may differ from user to user (e.g. 10 minutes or 1 hour), the notification about the training duration is critical. As a rule, sportsmen plan to exercise for a specific amount of time; they estimate the remaining duration of the training according to the passed time. Some professional sportsmen train for endurance; such athletes set a specific training time, and plan their exercising strategy based on time segments.

Distance unit covered. Similarly to the time units, many sportsmen train for specific distances. For example, for marathon runners it is an absolute requirement to know the covered mileage. The exact length of the distance unit can differ from user to user and depends mainly on the training goals and the kind of sport.

Additional information about objects on the track. This can be related to points of interest, city sights, trail-related notes, and tips from other sportsmen. When a sportsman approaches an object of interest, he wants to get some description of it. This is related to interactive notes which deliver entertaining information about the track: places of interest, training tips, avoidances, and so on. Such additional information is relevant for navigation on a new track. In competition mode, in contrast, the user concentrates on the race and personal performance. It is unlikely that he will be interested in any additional entertainment.

Wrong way scenario. This situation requires a special acoustical support, as it represents a false course of training. Once a sportsman has deviated from the intended path, a notification should warn him. Desirably, the notification sounds as early as possible, since larger deviations may cause more confusion and time loss for the sportsman. The acoustical feedback can also announce the right directions to return to the intended track.

Race situation change. In competition mode, the overview of the race situation is essential. The sportsman must to be updated immediately if his leadership is threatened, or on the contrary, if his chances to win are growing. The most representative way to deliver such information is to announce the gap change. If the sportsman is leading and he gets a notification that the gap is decreasing, it is an alarm to speed up. If the gap is increasing, the sportsman can calm down and keep on competing with the same pace.

Finish reached. During navigation on a new track, a sportsman should be notified when he reaches the finish. Usually, it doesn't mean that the training is over. At the finish the sportsman is free to decide to proceed with his training, or to fulfill only the recommended path. In the competition scenario both situations – when the user has reached the finish, as well as when his rival has finished – should be announced.

Changing directions can also be considered as important moments to keep track of. However, the interview results indicate no common opinion on this question. The majority of sportsmen who had previous experiences with voice navigators expressed their preference not to have this feature included into the sports assistant. For others, the question of voice directions was rather an abstract one: it is hard to imagine such functionality without trying it.

All in all, the training moments described above can be efficiently supported by acoustical feedback. In this way, a sportsman doesn't need to interrupt his training, look at the device screen, and interact with it. Just by hearing the acoustic hint the athlete is able to interpret the event and take a decision accordingly.

Among the audio modalities available for such acoustical feedback, we may use **signals and voice**. But which modality is the most appropriate for each event? In fact, if all mentioned training moments are assisted only by voice or only by signal, it may be annoying and lead to distractions rather than being supportive. Moreover, if the number of signals is significant, it is hard to associate them with different events, especially in stressful training situations and is difficult to define in which situations the voice or the signal is preferred. According to our interview results, the preference mostly depends on users' personal experiences with car GPS systems, with training devices, etc. In the following we describe the design and implementation of the prototype that enabled the evaluation of this question in a real sport scenario.

4 Design and Implementation

As the main design methodology for Mobota UI we have chosen "Iterative User Interface Design" (Nielsen 1994). For the first iteration of the DIA design process we started with creation of a paper prototype. The prototype was based on typical usage scenarios mapped to the design requirements. First of all, we considered the main use cases of Mobota system that are represented by the Mobota training modes: Record Only, Navigation, and Competition. The competition mode is implemented similarly to the navigation. Starting point for our developments and design considerations was the already existing mobile client of Mobota.

The paper prototype was tested heuristically and by user testing. The main design guidelines for the evaluation of our first prototype were ten usability heuristics (Nielsen 1994), Gestalt Theory, and Norman principles of visibility and affordances (Norman 1998). For testing with users we chose the "Think aloud" method. In total, 6 users participated in the testing; 3 of them were male and 3 female. The users were aged between 23 and 28 years old. Half of them are students, and half are working people. Professional backgrounds of the test persons included IT, economics, and engineering. In several cycles we moved from the paper based prototype to the final implementation that is presented in Figure 1.

Figure 1: Final look of Navigation and Competition modes

5 Evaluation

The final evaluation of the Mobota user interface aims at deriving patterns of the preferences for audio modalities (voice-signal pattern) in different training situations. To simulate real training conditions, we conducted the testing at jogging tracks frequently used by sportsmen. In total we have tested 20 people; 13 of them were male, and 7 female. The test persons were aged between 21 and 29 years. Most of them jog regularly or occasionally. Two persons participate in marathons. The test persons have different professional backgrounds: there were 12 students, 4 PhD students, and 4 working people. Our test persons had difference experiences with mobile devices: one third of them didn't have any experience with a PDA before, almost one third possesses smart phones (not touch-screen devices), and all test takers have mobile phones. None of the tested persons had previous experiences with Mobota.

Every user had to accomplish four tasks: run two tracks in navigation mode and two tracks in competition mode. For each task we used pre-recorded tracks. Although our testing took place in different cities (Bonn, Cologne, and Munich), the tracks were similar in their trajectories, length and duration. The test persons didn't know the trail paths before.

On each track all test takers encountered the following training situations: time/distance unit covered, user took a wrong way, two interactive notes (music tip and place of interest), and finish reached. In the competition scenario, they were additionally assisted with the feedback about changing gaps, but didn't receive interactive notes.

The testing was conducted using the within-subjects approach (Greene 2003): every test person heard both modalities of audio feedback: signal and voice. We have provided two tracks for navigation scenario and two tracks for the competition scenario. Audio modalities were distributed among the two tracks mirror-inverted: if the first track contained an announcement in voice, the second track contained the same announcement in signal form.

Although this approach may cause learning effects, it was important for us to let every person try both audio modalities. Without being able to compare both variants, a test person would not be able to decide on his preferences. To avoid expectation transfer from one modality to another, we switched the order of modalities from user to user.

In a typical training scenario the situations with audio feedback appear recurrently. The following table shows an example of a navigation scenario; a sportsman usually gets the feedback about time, distance, wrong way, etc. several times during the training.

Announce 1	Time: 10 min
Announce 2	Distance: 1 km
Announce 3	Wrong way taken
Announce 4	Time: 20 min
Announce 5	Interactive Note 1 “Sight”
Announce 6	Distance: 2 km
Announce 7	Interactive Note 2 “Tip”
Announce 8	Finish reached

Table 2: A typical course of events during a training supported with audio feedback

Beside observation of test persons and records of their impressions and comments, we asked users to evaluate every sound they heard on a scale from 0 (annoying, useless) to 5 (perfect, useful). The grade-based evaluation helped us to understand users’ preferences; moreover, it enabled us to analyze the preferences statistically and to derive a pattern for audio support. The grades given by each user were recorded in a protocol and visualized in chart diagrams. The following figure provides an example for the results of the gap change announcement.

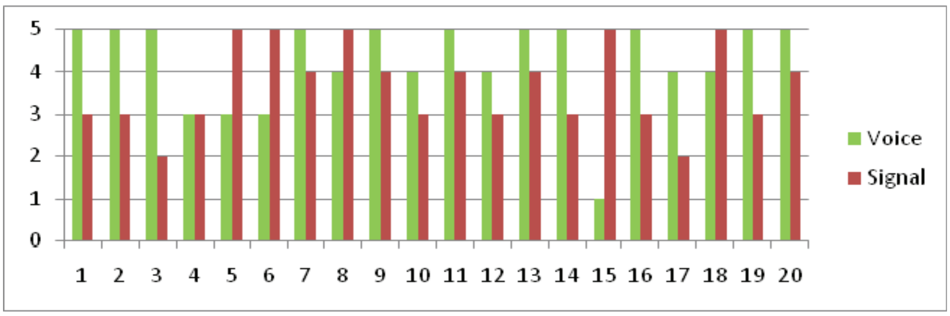

Figure 2: Grading of audio modalities for gap change announcement

In order to draw reasonable conclusions from the test results, we conducted statistical analyses with the obtained data. Since the grading scale from 0 to 5 represents an ordinal scale and the number of test persons is less than 30, we have used a non-parametrical method for statistical analysis (Conover 1998).

By means of Mann-Whitney U tests we can calculate the probabilities of two contradicting hypotheses:

- Hypothesis H0 = Preferences for Voice and Signal are distributed equally
- Hypothesis H1 = Preferences for Voice and Signal are not distributed equally

For each training situation we formulated these two hypotheses and calculated the probability of H0. If the probability of H0 < 5%, we reject H0. This would mean that the user preferences are not equal for both modalities. By counting the user votes for voice and signal, we conclude which modality is preferred. If the probability of H0 > 5%, we accept H0; in this case user preferences are equal for both modalities. According to the results of the statistical analysis, we derive the following pattern for audio support in training situations:

- **Time / Distance announcement – Voice:** For both announcements the probability of H0 converges to zero, i.e. the null hypothesis is rejected. Since the total number of higher grades for voice is much larger than those for signal, we conclude that accomplished time and distance units should be announced with voice.
- **Interactive notes – Mixed or user-defined:** The probability of H0 is more than 5%, i.e. we accept hypothesis H0. Thus, the pattern for audio modality is a mix of signal and voice, or the modality can be configured by the user.
- **Wrong Way scenario – Mixed or user-defined:** The probability of H0 exceeds 80%, i.e. the hypothesis H0 is accepted. The sound feedback for the wrong way scenario should appear either as a mix of signal and voice, or it can be set up by the user.
- **Finish – Mixed**: The probability of H0 for the finish situation is more than 90% i.e. we accept H0. That means that the audio feedback for finish should be either mixed or set by the user. However, our test observations and the remarks of the test persons clearly showed us that reaching the finish should be announced by a mix of signal and voice.
- **Gap change – Voice.** In case of gap change announcements, the null hypothesis H0 has a probability of less than 5%, i.e. we rejected H0. The distribution of user votes for voice and signal shows that the majority of test users voted for announcements with a voice.

Below we summarize the explanations and comments of our test users on why they have voted for a certain modality.

Time / Distance announcement: The information provided in such an announcement contains numeric data ("10 min.", "3 km") that is hard to code by signal. If the user knows the length of intervals when the announcement happens, he has to count how often the announcement has already been made. Such calculations are unacceptable in a training scenario. The information should come fast and be interpreted as quickly as possible. Therefore, the voice announcement is the easiest way to convey performance feedback. But, some users noticed that announcements are annoying, since sentences like "Time: 10 min." are too long.

Interactive Notes: The signal feedback for interactive notes was considered more interesting than voice feedback. The signal made users curious about the note: "What is inside the note?" Moreover, the signal for interactive notes was the most learnable signal. Although the users didn't know the meaning of the signal in advance, they learned it very fast, and interpreted it immediately the next time a new note appeared. However, some sportsmen may not be interested in all types of interactive notes. In this case the signal feedback doesn't distinguish the types of the note, and hence the user cannot filter out the notes of interest. A voice announcement of the note type solves this problem. If the user approaches a note assisted by "Point of interest" phrase, he can ignore it without any interruptions of his training.

Wrong Way: In a wrong way situation an alarming signal gives a strong hint that something went wrong. In outdoor environment such a signal is easier to identify than a sentence in voice. The sentence, e.g. "You took a wrong way" may be missed due to the street noise; it can also be mixed up with other voice announcements, and not be considered properly. However, the voice assistance was generally considered more supporting. It simulates human support which is very important in the negative course of events such as the wrong way situation.

Finish: The majority of test users appreciated both audio modalities for finish announcements. An important comment from test users concerned the emotional character of the finish announcement. When a sportsman reaches the finish, he feels like having accomplished a big task, and expects to get some awarding gratification. Therefore, at the finish users would like to hear applause, greetings, and the blare of trumpets.

Gap Change: In race situation sportsmen appreciate emotional support as well. A signal can barely provide this support; it appears rather artificial and sounds indifferent to the user's achievement. The voice simulates human support in a competition situation. If the race status gets worse for the user, a boosting voice sentence would sound inciting. Phrases like "Go! Go! Go!" or similar slogans are preferred as a race support.

6 Conclusion

In this paper we have researched the user requirements for mobile training assistants and applied them to the Mobota user interface. The requirements define visual and audio design guidelines for user interfaces of the training assistants. We have based our research on the assumption that performance feedback, navigation on the track, competition support, and entertainment are the essential functions required for outdoor training. Employing a user-centered approach, we have derived the design requirements for these four functions.

We have applied the design requirements to Mobota user interface following the DIA methodology. Formative evaluation was conducted over intermediate prototypes. In the process of formative evaluation we revealed several usability issues and detected deviations from the initial user requirements. For example, the interviewed sportsmen were not willing to have audio announcements of navigation directions; such announcements were mostly considered annoying and distracting. However, the formative evaluation revealed the necessity of this announcement.

Summative evaluation was applied to the final prototype of the system. The goal of the final evaluation was to derive a pattern of signal-voice modalities for the support of critical training situations. Testing was conducted following a within-subjects strategy, so that every test person was able to hear and evaluate both kinds of audio modalities. Statistical analyses of the answers revealed a distribution of user preferences that contribute to design recommendations for auditory feedback in training situations.

All in all, the system was found very entertaining and useful as a training support. In particular, the concept of interactive notes received a lot of positive feedback. It was considered not only entertaining, but also motivating to explore the track. The competition mode, supported by map visualization and auditory feedback, was also appreciated as an outstanding motivation source. The desire to win raises the spirit and incites sportsmen to improve their training performance.

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